Proposed Fermilab Contributions to Future Muon Accelerator R&D

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Outline

- Introduction
- Organization and Personnel
- Recent Accomplishments

} Alan's talk

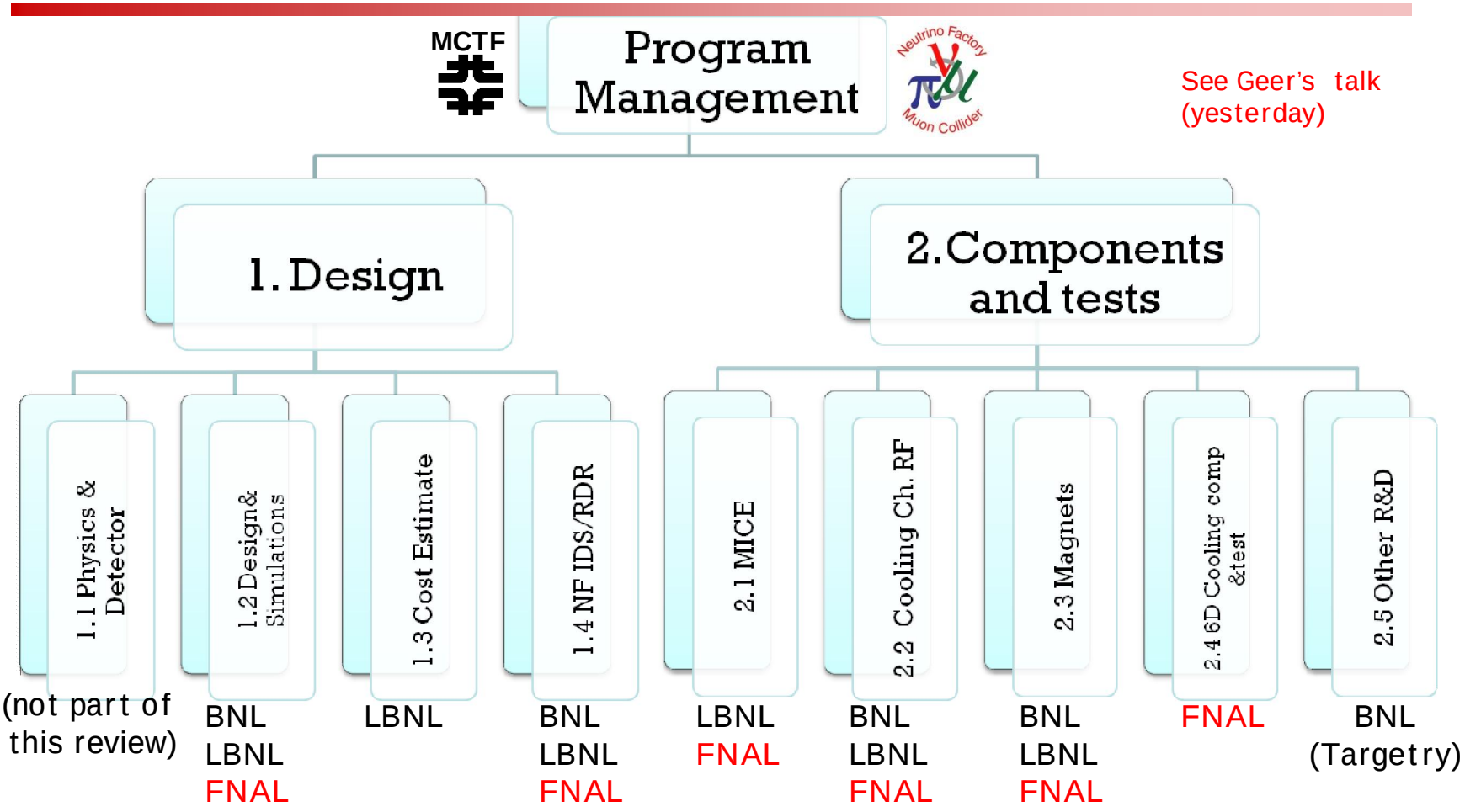
- **Proposal for FY2009-2012**
- **Budget Request**

} This talk

Why Muon Collider R&D at Fermilab

- With the start-up of the LHC, the focus at Fermilab is currently shifting from energy frontier to intensity frontier (Project X).
- A Muon Collider is a possible future option for Fermilab (and the US) to get back to the energy frontier.
  - A multi-TeV Muon collider would fit the on the Fermilab site.
  - Production of muons would make use of the intensity frontier capability currently being proposed.
  - A first step towards a Muon Collider could be a Neutrino factory (which is also a further extension of the intensity frontier).
- Fermilab has unique capabilities to perform Muon Collider R&D
  - Experienced staff with right background and expertise
  - Special facilities (MuCool Test Area, Magnet factory/test facility, etc)

The Joint MC R&D Plan



(only the three sponsoring labs shown, other institutions also involved)

Caveat

- The 5-year Muon R&D plan extends beyond the 3-year time frame which is the scope of this review.
  - Some tasks do not finish (or have milestones) in the FY09-11 period.
- The plan outlines the R&D that needs to be done, and the resources required to do it.
  - The execution of the R&D tasks will be coordinated between the collaborating labs/institutions
  - Fermilab's strategy is to focus on the critical items where we will have the most impact.
- This talk will give an overview of the proposed Fermilab share of the plan in the next three years.
  - Note that this is a collaborative effort, and Fermilab does not exclusively own the tasks mentioned.

Proposal for FY2009-2011

- Design and simulations
- Neutrino Factory IDS/RDR
- MICE
- **Cooling Channel RF**
- Magnets
- 6D cooling channel components and test
- Management and organization

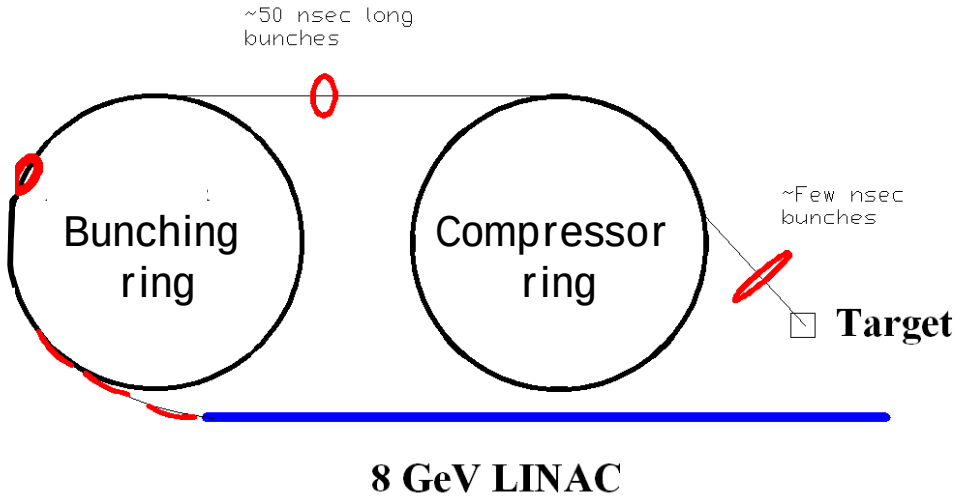
Design & Simulations

- The 5-year plan includes a detailed plan, listing the simulation studies that need to be performed.
- The distribution of this work will be coordinated among the participating labs.
- Areas where Fermilab is, and will be, involved include
  - Proton driver (e.g. extensions to Project X)
  - Front-end (capture and bunch rotation)
  - Cooling channel (e.g. HCC and FOFO snake)
  - Muon acceleration (e.g. RF issues)
  - Collider ring design (e.g. IP optics)
- Fermilab's contribution is expected to grow from currently about 4FTE to 16FTE in 5 years (as Tevatron effort ramps down).

7.9FTE average effort FY09-11

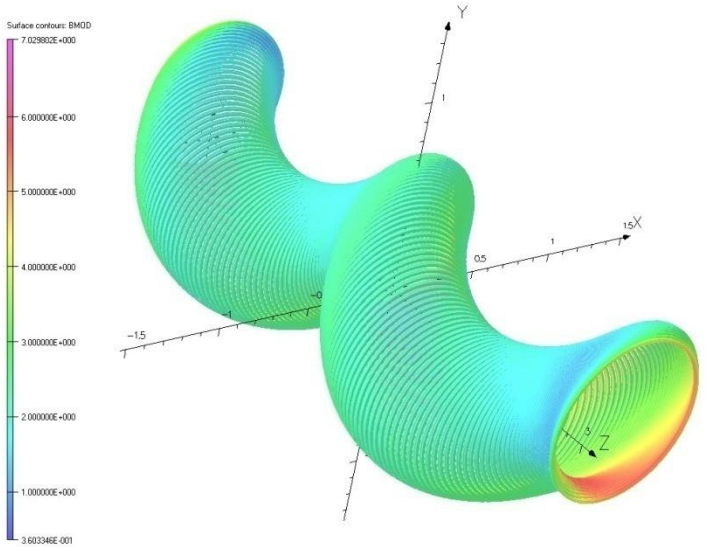
Project X

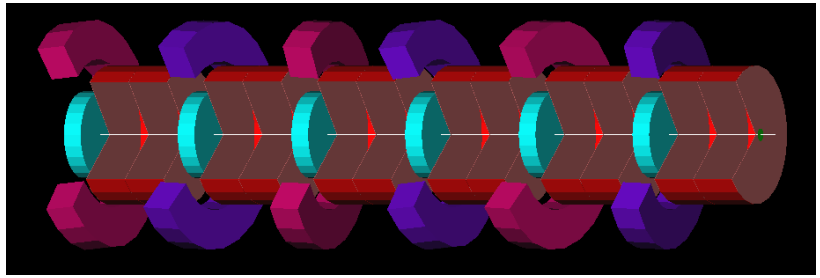
- We would like to make sure the appropriate upgrade capability is built in from the start, by interfacing with design team.
  - Official design values have been adjusted based on MC input
  - 1MW at 8GeV, upgradable to 4-5MW at 8GeV
- Using Project X to feed a Muon Collider (or NF) would require one, or more likely two, new rings to repackage the beam before hitting the target.
  - Ring lattice
  - Re-bunching
  - Instabilities
  - Intensity effects



6d Cooling Channel Simulations

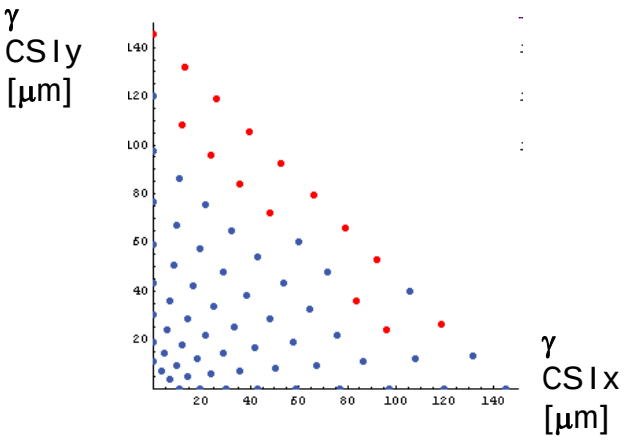
- Further HCC simulations, in collaboration with magnet and RF designers, to find engineering solution for including RF cavities.
- Investigation of FOFO snake which could possibly cool both types of muons simultaneously.
- Prepare for an end-to-end cooling channel simulation.

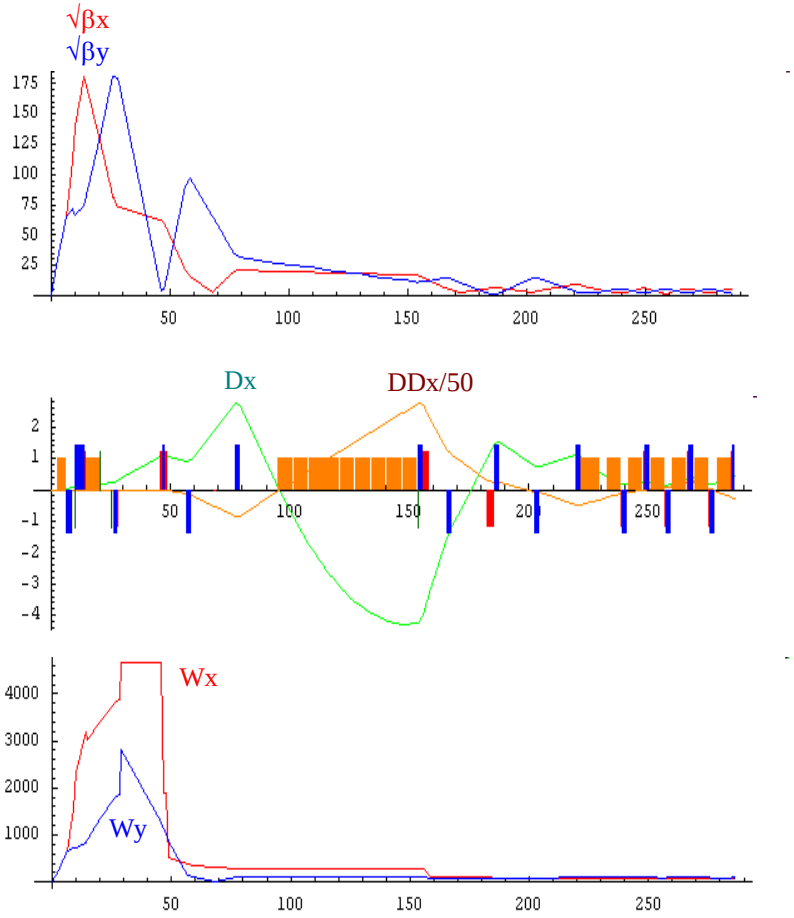




Collider Lattice Design

- Continue studies of collider lattice
  - e.g., chromatic correction and dynamic aperture





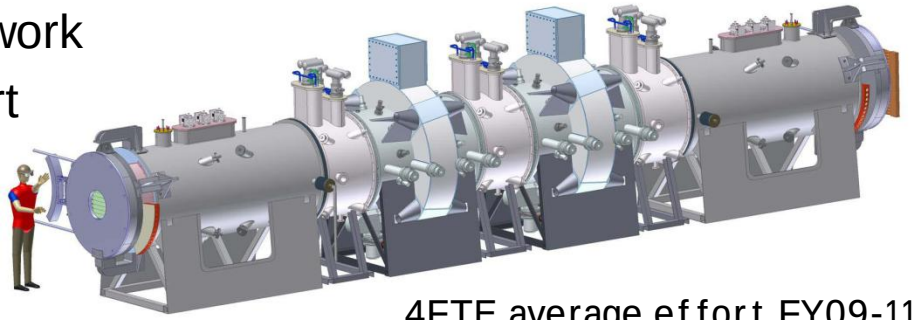
NF-RDR / IDS

- Front-end (capture, phase rotation and cooling)
  - Dave Neuffer is IDS coordinator for Front End.
  - Front end is highly synergistic with Muon Collider.
- Site specific (Fermilab) geological engineering studies
  - With DUSEL
- Muon acceleration
  - Some effort on FFAG (coordinated by S. Berg, BNL)
- Target
  - Small effort on simulations in support of target development
- Neutrino detector
  - Magnetization of very large volume [not part of this review]

2FTE average effort FY09-11

MICE

- MICE is an existing commitment
  - Aim is to demonstrate 4D cooling by 2012
- Fermilab's hardware contributions to MICE will be delivered by mid-2009
  - Mapping and testing of the Spectrometer Solenoids
  - Beamline profile monitors
  - Spectromenter (Fiber-tracker, cryoboxes, electronics, etc)
  - LiH absorber disks
- Remaining involvement mainly personnel and travel
  - Support exploitation/shiftwork
  - Some engineering support
  - Hire postdoc



4FTE average effort FY09-11

Cooling Channel RF

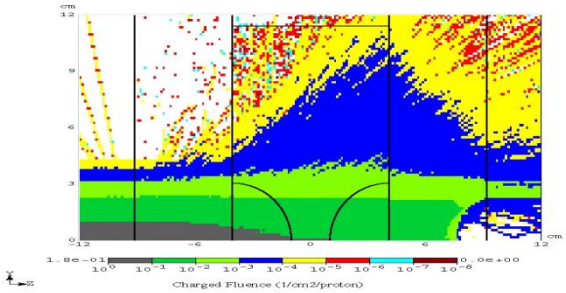
- One of the most important objectives for Muon Collider R&D in the next three years is to demonstrate **at least one** RF technology that works (with beam) in a multi-Tesla magnetic field. Candidates include:
  - Cavities filled with high pressure gas
  - Vacuum cavities treated with cleaning techniques developed for superconducting cavities
  - Vacuum cavities treated with Atomic Layer Deposition (ALD) See Norem's talk (ANL)
  - Vacuum cavities shaped so that the high field surfaces are parallel to the magnetic field lines ("magnetic insulation") See Kirk's talk (BNL)
- Most of the development and all of the testing of these cavities will be done at Fermilab.

5.3FTE average effort FY09-11

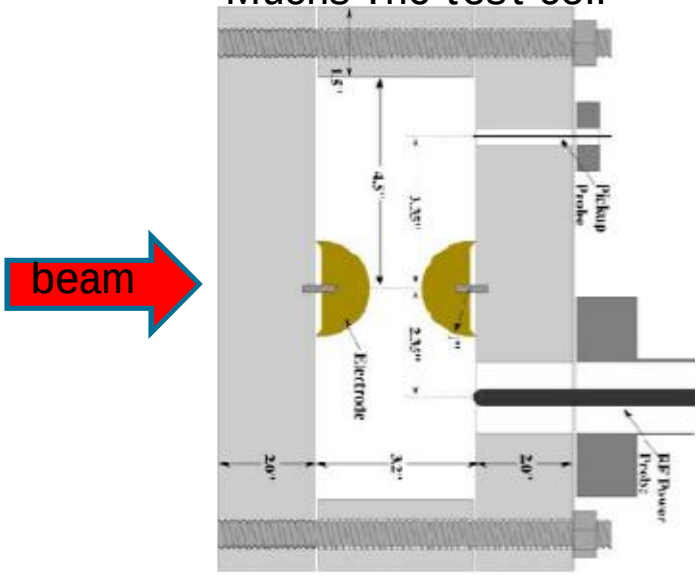
First HPRF Beam Experiment

- We know high pressure gas can suppress breakdown in RF cavities.
  - What happens when an intense beam passes through the cavity?
- MTA beam line is currently being commissioned.
  - Linac proton beam can generate ionization levels similar to muon beam (6 10^{12} protons equals ~1.2 10^{13} muons)
- Beam tests will be done in collaboration with Muons, Inc (SBIR).
  - First test will use the existing Muons, Inc test cell
  - Follow-up test will likely require building a "real" cavity

Beam simulation

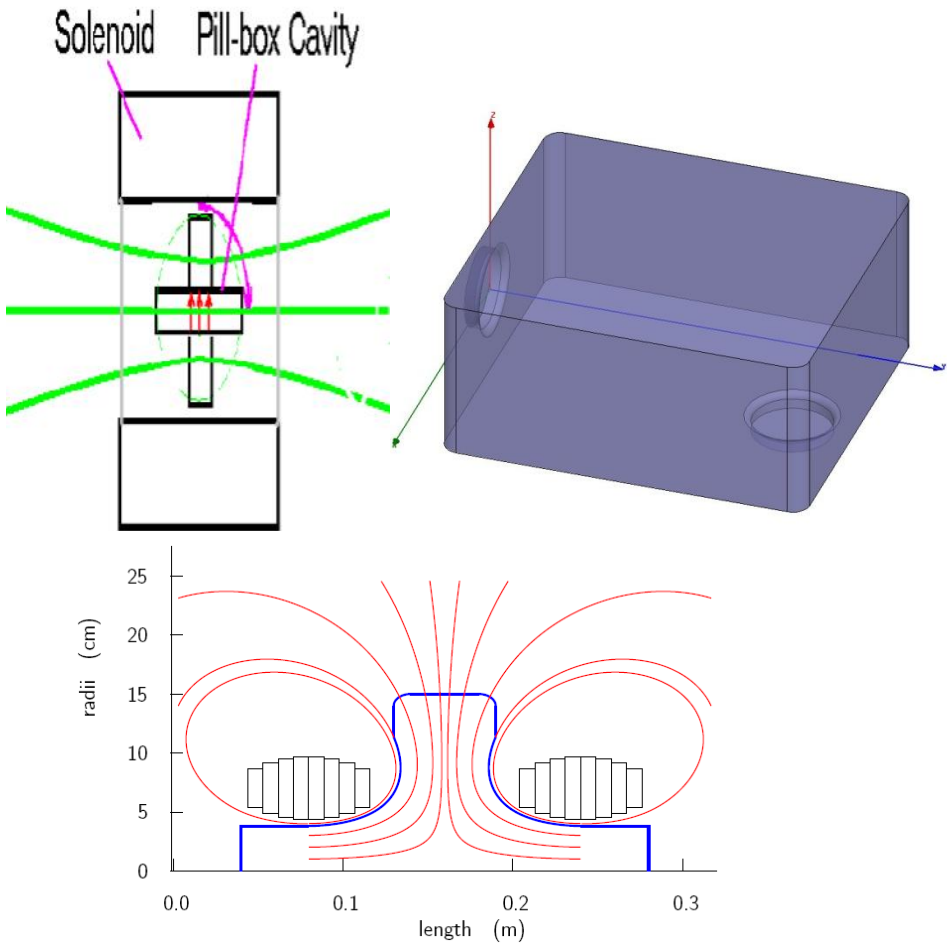


Muons Inc test cell



Magnetic Insulation Test

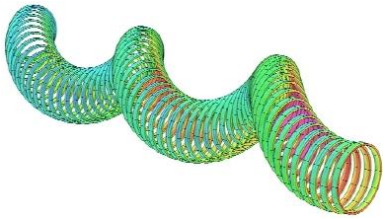
- Measure the peak achievable gradient vs the direction of the magnetic field.
- Expect breakdown to be suppressed when E and B are (approximately) perpendicular
- If test successful, next step would be to build magnetically insulated cavity

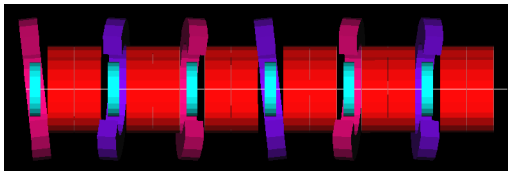


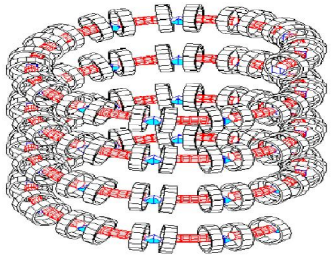
Path to a 6D Cooling Channel

In the next couple of years, we plan a number of critical RF tests, each potentially leading up to a demonstrated 6D cooling channel

RF test	Test HPRF cavity with beam at MTA	Measure E_{max} as a function of the direction of B in simple pillbox cavity	Test ALD treatment of simple normal conducting cavity in strong magnetic field	Test 805MHz cavity cleaned with SC cavity methods in strong magnetic field
	Build and test "real" HPRF cavity	Build and test magnetically insulated cavity	Verify longevity of surface. Test in situ treatment of real cavity.	Build 201MHz cavity and test in realistic field
Section test	Build and test section of HCC with RF	Build and test Guggenheim section incorporating magnetic insulation	Build and test (regular?) Guggenheim section	Build and test (regular?) Guggenheim section
	HCC 6D cooling experiment	Magnetically insulated Guggenheim (or snake) 6D cooling experiment	Guggenheim (or snake) 6D cooling experiment	Guggenheim (or snake) 6D cooling experiment



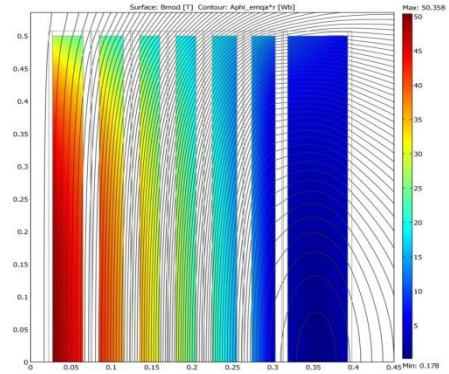


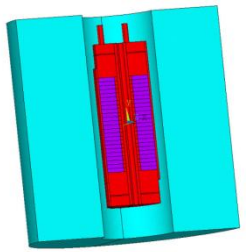


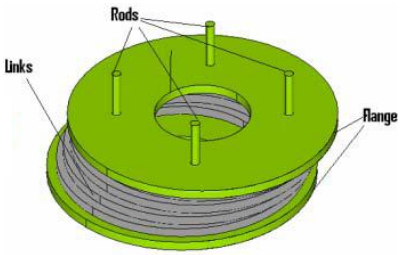
The majority of this work will be done at Fermilab!

Magnets

- High Field Solenoids
  - More than 30T (50T preferred) needed for the final cooling
  - Paper studies of solenoid design
  - Small HTS inserts
  - HTS conductor development (BSCO) will be done in new national collaboration
- Helical Cooling Channel magnets
  - Build model magnets to test concepts
  - Paper studies on full magnet design, incorporating space for RF
- Magnet cost models
  - To aid first MC cost estimate (small effort)







4.5FTE average effort FY09-11

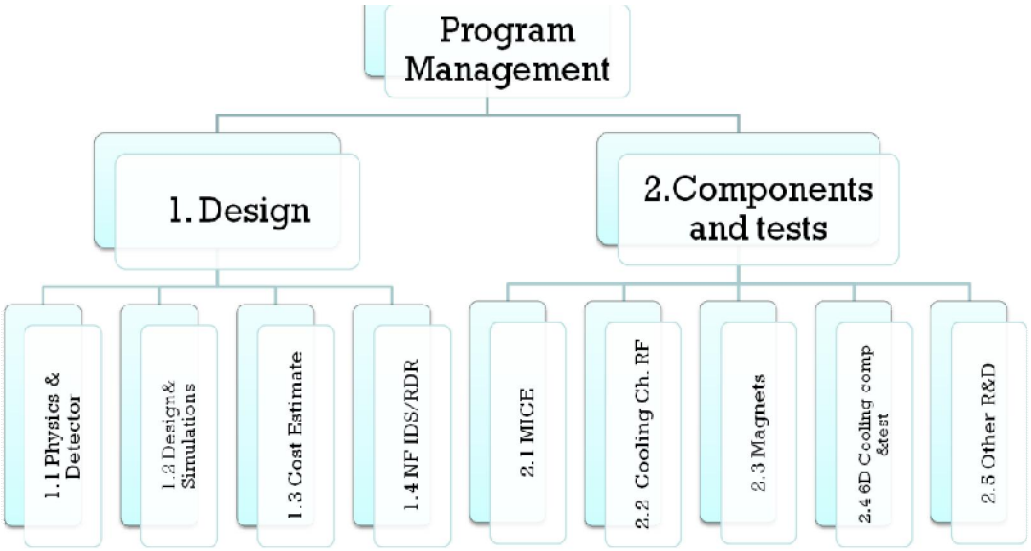
6D Cooling Channel Components and Test

- Once we have an RF technology that is proven to perform well in magnetic field (with beam), we would like to proceed with building a section and bench test it
- Fermilab would play a major role in building a section of either Helical Cooling Channel or Guggenheim ring.
- Both bench tests will likely be done at Fermilab (in MTA)
- The timescale for these tests in the 5-year plan is 2011-2013 (beyond the period currently being reviewed).
  - Preparations for such a test will be done in the next three years (mostly towards the end).
  - At the end of FY11, we should know what to build and have started the design work.

2.3FTE average effort FY09-11

Management

- Fermilab staff will have a significant involvement in managing and coordinating the overall Muon R&D program



1.7FTE average effort FY09-11

Manpower requirements

Overall 5-year plan:

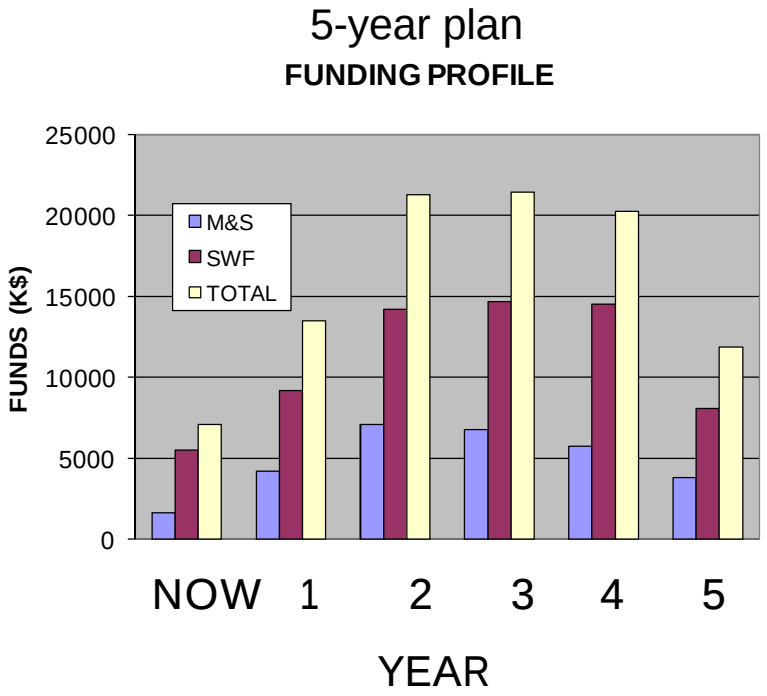
	Now	Year 1	Year 2	Year 3	Year 4	Year 5
BNL	6.5	7	8	10	10	10
FNAL	20.8	23	28	30	33	33
LBNL	2.5	6	8	9	11	13
Other	7	13	35	32	32	32
TOTAL	35.6	49	79	81	86	88

Fermilab proposed contribution:

	FY08	FY09	FY10	FY11	FY12	FY13
1.1 Physics & Detector	0	0	0	0	0	0
1.2 Design, Simulations, Report	3.5	3.7	8	10	12	16
1.3 MC-DFS Costing	0	0	0	0	0	0
1.4 NF-RDR	0	2	2	2	1.5	0
2.1 MICE	5	4	4	4	2.5	1
2.2 RF R&D	8.3	7	5	4	3	3
2.3 Magnet Studies	3	4.5	4.5	4.5	4	3
2.4 6D Cooling Sections & Tests	0	0	3	4	7	7
2.5 Other R&D	0	0	0	0	0	0
3 Management	1	1.5	1.5	2	3	3
TOTAL	**20.8**	**22.7**	**28**	**30.5**	**33**	**33**

M&S Budget

- Detailed distribution of M&S funds will be coordinated among the participating labs/institutions.
  - Plan total is ~ $88M, about 1/3 of which is M&S.
  - Expected Fermilab manpower contribution is about 40% of total, M&S budget share may be roughly same order.

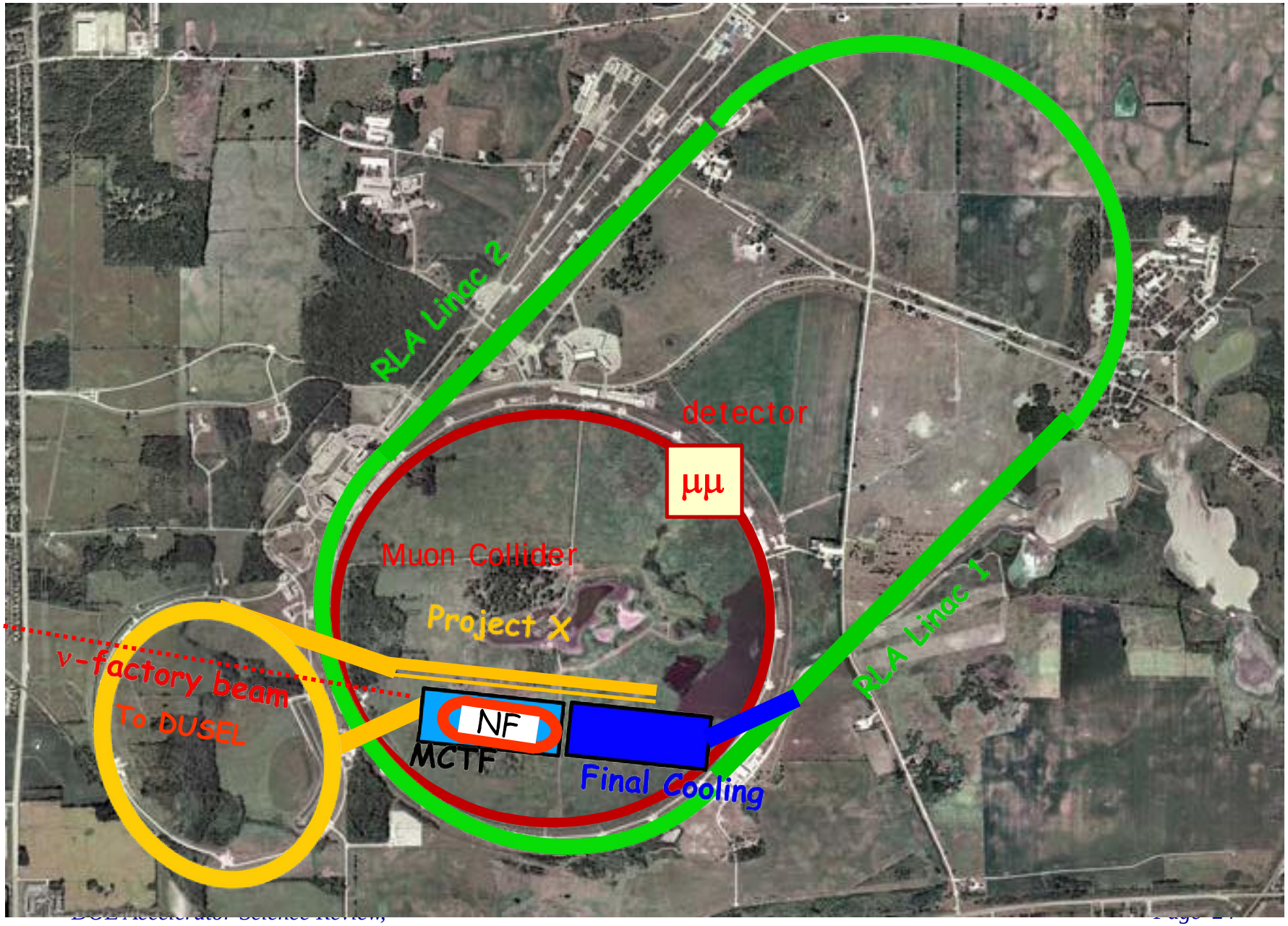


Fermilab Summary

- A Neutrino Factory and/or Muon Collider is a possible future option for Fermilab.
  - A Muon Collider could put the US back on the energy frontier.
- There is a 5-year Muon Accelerator R&D plan on the table.
  - Aim is to demonstrate Muon Collider Feasibility by ~2013.
  - Requires significant increase in resources from OHEP.
- Fermilab proposes to play a major role in Muon Collider R&D over the next few years.
  - Involvement in IDS, MICE, RF R&D, Magnet Design and 6D cooling channel development, as well as management and scientific oversight.
- In the next three years, we expect crucial RF test results that will aid in down-selecting the 6D cooling channel options.
  - These tests will be done at Fermilab.

Road Map to the Future

- We believe ~2012 will be a pivotal time in HEP
  - LHC Physics results
  - Neutrino data from reactor and accelerator experiments
    - Double Chooz Daya Bay
    - MINOS, T2K ,Nova
  - Major Studies for Frontier Lepton-Colliders completed
    - ILC TDP (Technical Design Phase)
    - CLIC CDR (Conceptual Design Report)
- Many exciting results – Will point us in some direction
  - We don't know which one yet
  - Need to prepare now to be ready then
    - Muon DFS (Design Feasibility Study)


RLA Linac 2
detector
μμ
Muon Collider
Project X
ν-factory beam
To DUSEL
NF
MCTF
Final Cooling
RLA Linac 1